The Propulsion Committee

Committee Chairman: Prof. Anthony F. Molland
Session Chairman: Dipl. Ing. Jürgen Friesch

1. DISCUSSIONS

1.1 Discussion to the 24th ITTC Propulsion Committee by Mehmet Atlar, Robert Mutton and Martin Downie, University of Newcastle upon Tyne, United Kingdom

We congratulate the Committee on their fine work in overall and would like to bring an emerging development as an addition to in their review of the state-of-the-art developments (Task 1). This is in relation to the increasing number of applications for propeller coatings to protect against to marine fouling and to improve the propeller performance. This will have potential impact on the ITTC regarding to performance evaluation of propulsors and we therefore would like to report on some of our ongoing research activities highlighted below.

In the ongoing battle against the derogatory effects of marine fouling, work has concentrated on preventing the build up of fouling on the surface of ship's hulls. This has lead to the effect of fouling on marine propellers being somewhat overlooked. However, in terms of energy lost per unit area, the propeller is more significant than the hulls. Keeping a propeller free from fouling therefore is a method of providing significant reductions in fuel consumption for relatively little investment. Furthermore, one of the important contributions to the propeller losses, apart from those associated with potential effects in accelerating the flow, is that associated with the frictional effect. By taking into account the limitations due to cavitation and strength considerations, the propeller designer has been left with a very little room to reduce this loss component by reducing the blade surface area and blade thickness, respectively. Within this respect keeping the blades regularly polished, either by divers or in dry dock, helps but this has the disadvantage that with the resumption of service, the propeller begins to degrade once more.

As a longer term solution to propeller blade maintenance, Newcastle University has been actively researching the use of modern non-toxic, silicone based, compliant coatings on propellers to prevent propeller degradation and fouling in collaboration one the world's leading paint manufacturers. These coatings were chosen for a number of reasons including their environmentally benign nature, proven drag benefits and their known antifouling capability. This research has shown that there are benefits to be gained from the use of such coatings for at least 37 months after coating.

The paints provide two methods of providing benefits to the ship owner. The coatings used, on first application provide a smooth surface [Ra 2.5 ~ 5microns] in a similar way to polishing, computer simulations conducted by Newcastle University have shown the coating has the equivalent drag of a new or well polished propeller as reported by (Atlar et al., 2002 and 2003). The coatings additionally then prevent the re-degradation of this surface through their antifouling ability. The Newcastle University research vessel, “Bernicia”, had its propeller coating in June 2003. It has been inspected after 12 and 24 months and to date has only shown a little light slime present on the inner part of the blades as shown in Fig. 1.1 while its uncoated propeller developed hard shell fouling (e.g. barnacles, tube worms etc) after 14 months as shown in Fig. 1.2.

To date over 150 full-size propellers have been coated by one the world’s leading coating manufacturers. Feedback from these vessels has shown a number of benefits as well as fouling free propellers up to 37 months (without cleaning), see Fig. 1.3. Crew have reported reduced noise and vibration, less propeller slip and reduced fuel consumption.

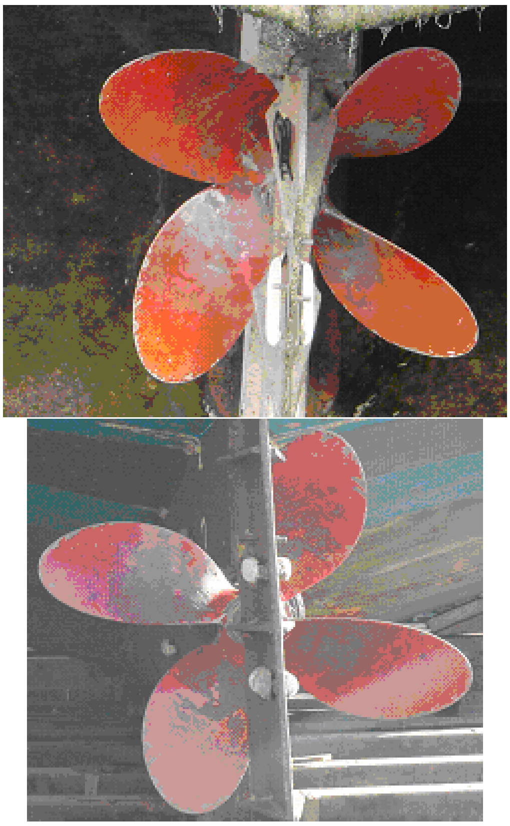

Figure 1.1- The propeller of “Bernicia” after 12 months in service (top picture) and 24 months in service (bottom picture) after coating. Almost 95% of the coating is intact, except some detachment of the blade edges. Light slime fouling is present on the inner half of the blades (grey material on the red coating is the dried biofilm). This could be easily removed by hand or with a damp cloth (Mutton et al., 2005).

Figure 1.2- The propeller of “Bernicia” after 14 months in service before coating. Hard shell fouling is present to half the blade radius (Mutton et al., 2005).

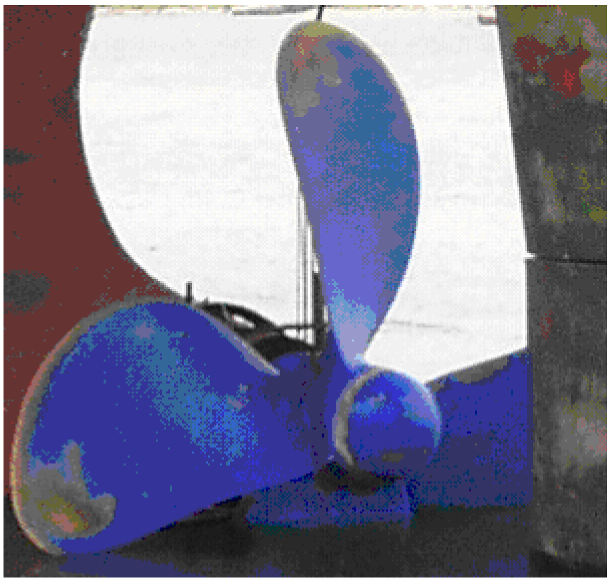

Figure 1.3- Full scale propeller after 37 months in service without cleaning, some light slime only (Mutton et al., 2005).

Newcastle University has conducted sea trials using “Bernicia”, which showed no significant change in performance due to the coating, the results were tempered however by poor weather on the coated propeller trials as reported in (Mutton et al., 2004).

According to the cavitation tunnel tests conducted in the Emerson Cavitation Tunnel of Newcastle University, the application of the coating provides no significant negative effect on propeller efficiency and at some advance coefficients actually appeared to increase performance as shown in Fig. 1.4, (Mutton et al., 2005). The model tests also showed how damage to the coating had no appreciable effect on performance until well beyond the level of damage seen on the full-scale vessels. Noise measurements and cavitation observations were also recorded.

A number of problems still remain to be addressed with the coatings. The major drawback at the moment is the mechanical strength of the silicone based coatings. The coating is typically removed from the leading and trailing edges of the blades and about 5% of the coating at the tip. A major source of this damage is thought to be cavitation. There is currently active research by the coatings manufacturers into improving the mechanical strength of the coatings without reducing their antifouling capabilities. A number of people have suggested that while the intact coating reduces propeller corrosion, damage to the coating may lead to higher rates of corrosion in the exposed areas. A detailed investigation into this aspect needs to be conducted. Newcastle University is also currently researching the effect of the slime layer on the propeller performance as well as further sea trials and detailed model tests to fully investigate the effects of the coatings.

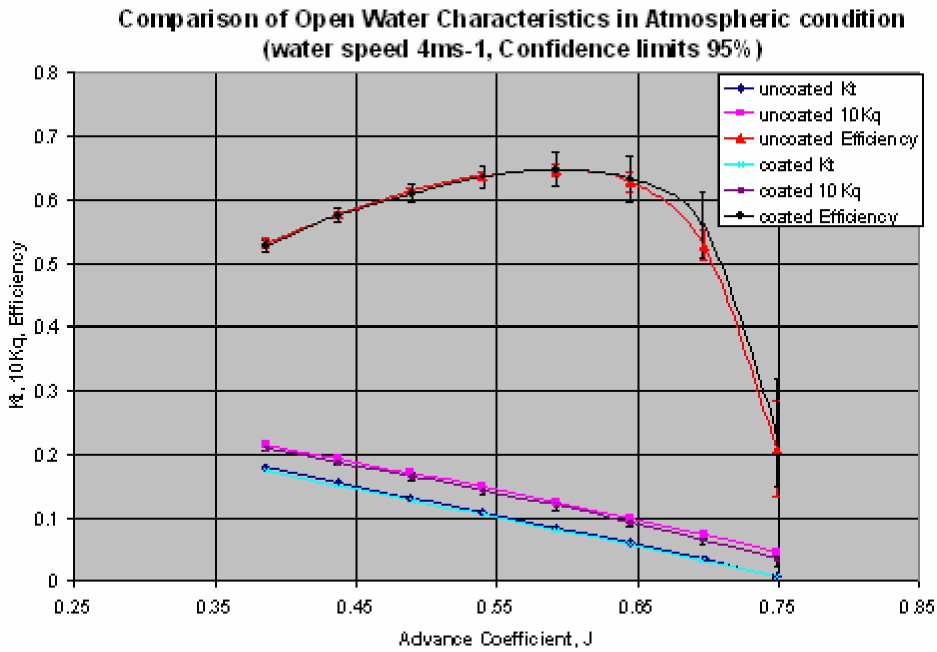

Figure 1.4- Model Test results (Mutton et al., 2005).

<u>References.</u>

Atlar, M., Glover, E.J., Candries, M. Mutton, R.J. and Anderson, C.D., 2002, "The Effect of a Foul Release Coating on Propeller Performance", <u>ENSUS 2002</u>, University of Newcastle upon Tyne, December 2002.

Atlar, M., Glover, E.J., Mutton, R. and Anderson, C.D., 2003, "Calculation of the Effects of New Generation Coatings on High Speed Propeller Performance", <u>2nd International Warship Cathodic Protection Symposium and Equipment Exhibition</u>, Cranfield University, Shrivenham, February 18-20.

Mutton, R.J., Atlar, M. and Anderson, C.D., 2004, "Propeller Fouling Control using Foul Release coatings", 12th International Congress on Marine Fouling and Corrosion, RINA, Southampton University, July 2004.

Mutton, R.J., Atlar, M., Downie, M. and Anderson, C.D., 2005, "Drag Prevention Coatings for Marine Propellers", 2nd International Symposium on Seawater Drag Reduction, Busan, Korea, 23rd-26th May 2005.

1.2 Discussion to the 24th ITTC Propulsion Committee by Stuart Jessup, Naval Surface Warfare Center, Carderock Division, USA

I would like to ask if trailing edge specifications were included in the Propeller Tolerance specification.

Trailing edge shapes, if they include anti-singing edges can affect thrust and influence thrust identity and setting of operation conditions in cavitation tunnel.

1.3 Discussion to the 24th ITTC Propulsion Committee by Tao Jiang, DST-Development Centre for Ship Technology and Transport Systems, Germany

First of all, I would like to express my sincere thanks for the comprehensive efforts of the Propulsion Committee.

Regarding to the proposed method by Jiang (2001) for an accurate prediction of resistance and powering performance, I would like to make the following comments:

The method was derived from many series of model tests for difference ships at different water depths. However, for predicting at different water depths or bottom topographies, one needs only a reference series of model tests just at one specific water depth, for instance in deep water.

The crucial parameter is the so-called mean sinkage. If it is known for the water depth considered, the conversion of resistance and propulsion characteristics from those at the reference depth is simple and accurate. The mean sinkage could be either approximated by means of empirical formulae or by using numerical methods, see Jiang and Friedhoff (2003).

References.

Jiang, T. and Freidhoff, B., 2003, "A heuristic method for converting the resistance and propulsion characteristics from one water-depth to another one", Proc. STG-Jahresbuch.

1.4 Discussion to the 24th ITTC Propulsion Committee by Do Ligtelijn, Wärtsilä Propulsion Netherlands BV, The Netherlands

The Report of the Propulsion Committee contains many interesting subjects, and is a valuable addition to the data propeller designers can rely on in their daily work. Chapters 8 and 9 address cavitation correlation and container ships issues. During 4 years our company, together with MARIN, with support of a number of ship owners and shipyards, were able to gather 5 unique sets of data on correlation of cavitation. On five different ships (of which two were containerships) speed – power data, cavitation observations and hull-pressure measurements were carried out. After that model tests were conducted at the same conditions as met during the sea trials, and also analyses by computational methods were done. In this way a unique set of model and full-scale data was obtained. One of the reasons to publish these data was to share our experience with the naval architecture community, and last but not least to (implicitly) encourage the ITTC to study the lessons learned and possibly come forward with improved testing and/or extrapolation methods. I would kindly like to ask the next Propulsion Committee to consider this unique set of data provided in Ligtelijn et al. (2004), and to report on it in their next Committee Report, since the paper concludes among others (supported by our experience) that some of the correlation problems relate to model testing in general and not to one model basin only. It must be said on the other hand that much of the experience published in the paper is in line with the findings of the Specialist Committee on Hull-pressure Fluctuations of the previous ITTC, which makes it worthwhile to consider from that point of view also.

References.

Ligtelijn, J.T., van Wijngaarden, H.C.J., Moulijn, J.C. and Verkuyl, J.B., 2004, “Correlation of Cavitation: Comparison of Full-Scale Data with Results of Model Tests and Computations”, SNAME Annual Meeting, Washington DC, USA.

1.5 Discussion to the 24th ITTC Propulsion Committee by Tom van Terwisga, MARIN and Delft University of Technology, The Netherlands

In Section 9.3 – Pressure fluctuations, the Committee states that the cavitation tests be performed in the simulated full-scale wake. A statement which I would support from a theoretical viewpoint. The problem is however, in simulating a sufficiently accurate wake field at model-scale. The Committee does not give any guidelines or references on how this should be done. Could the Committee expand on this experimental scaling procedure?

In the discussion, an efficiency improvement of propulsors and the role of coated propeller blades in this efficiency (comment by M. Atlar during discussion), could the Committee indicate priorities in the various measures that have been proposed.

Would it be timely to re-assess the energy saving devices with the latest development in CFD and experimental procedures?

1.6 Discussion to the 24th ITTC Propulsion Committee by Yanying Wang and Lijun Zhang, Dalian University of Technology, China, on Validation for a Numerical Hydrodynamic Performance for a Marine Propeller

A potential-based panel method for hydrodynamic analysis of marine propellers in steady flow is developed. The method is based on the Green’s theorem composed of the combination of constant source and dipole distribution on the surface of blades and hub, with dipole distribution on the trailing wake to represent the potential flow around the propeller. A wake model (Hoshino, 1989) is used in present method, which is developed specifically for heavily loaded marine propellers. Moreover, special attention is paid to the pressure Kutta condition (Kerwin et al., 1987) at the trailing edge. The computational results including hydrodynamic force and pressure distributions for the propeller DTRC4119 are compared with numerical solutions by Hoshino (1999) and experimental measurements (Jessup, 1994) and shown good agreement with them.

Mathematical Formulation. The fluid in the domain is assumed to be incompressible, inviscid and irrotational and then there exists a perturbation velocity potential ϕ, which satisfies the Laplace equation:

$$\nabla^2\phi = 0 \qquad (1.1)$$

Using Green’s theorem, the perturbation velocity potential at any point can be written as an integral equation in terms of source and normal dipole distributions. A boundary value problem can be constructed by specifying the boundary conditions. Thus, for the field point P in the domain, it can be obtained:

$$2\pi\phi(p)=\iint_{S_B}\left[\phi(q)\frac{\partial}{\partial n_q}\frac{1}{R(p,q)}-\frac{\partial\phi(q)}{\partial n_q}\frac{1}{R(p,q)}\right]\mathrm{d}S+\iint_{S_W}\Delta\phi(q)\frac{\partial}{\partial n_q}\left(\frac{1}{R(p,q)}\right)\mathrm{d}S \tag{1.2}$$

where,
$\phi(p)$ is perturbation velocity potential;
$p(x,y,z)$ is field point where induced potential is calculated;
$q(\xi,\eta,\zeta)$ is source point where singularity is located;
$\frac{\partial}{\partial n_q}$ is normal derivative with respect to the point q;
$R(p,q)$ is the distance between p and q.

Equation 1.2 is a Fredholm integral equation of second kind for the velocity potential ϕ and can be solved uniquely. The resulting surface potential distribution can be differentiated to obtain velocities and pressures, which are integrated to yield the total forces and moments.

Discretization Equation. This system of equations can be written in a matrix form as follows:

$$[A][\phi]=[B]+[W][\Delta\phi] \tag{1.3}$$

[A] = influence coefficients matrix of dipole induced potential;
[B] = influence coefficients matrix of source induced potential;
[W] = influence coefficients matrix of dipole induced potential.

These influence coefficients are evaluated analytically by the equation of Morino (1974). In actual numerical computation, the calculation of the matrices [A], [B] and [W] is very time consuming. In present paper, the Gauss-Seidel method is used to solve the equation system to get the values of unknown potential ϕ .

Wake Model. The trailing vortex wake is divided into two parts, transition wake region and ultimate wake region. The variations of radial positions and hydrodynamic pitch are considered. Meanwhile, the variation of the hydrodynamic pitch is taken into consideration. The calculation of tip vortex radius in the ultimate wake based on the momentum theory (Breslin and Andersen, 1994 and Ghassemi et al., 1995) is given as follows:

$$r_{ut}=\left(\frac{\sqrt{1+C_T}+1}{2\sqrt{1+C_T}}\right)^{\frac{1}{2}}\cdot R \tag{1.4}$$

where,
C_T is thrust coefficient; R is the diameter of propeller.

Kutta Condition. The pressure Kutta condition is imposed to specify the circulation around the propeller, which is equal to the potential jump in the wake surface. It is expressed as:

$$\Delta p_T(m)=0,\ m=1,\ldots,N_R \tag{1.5}$$

where,
N_R is panel number in radial direction. In the present method, the pressure Kutta condition is applied at the exact location of the trailing edge instead of at the control points on the panels adjacent to the trailing edge. To some extent, it is beneficial for the convergence of the iteration process.

Comparison. The pressure distributions of blades at 0.3, 0.7, 0.9 radii for propeller 4119 are calculated. The calculated results are compared with the experiment results and Hoshino (1989) calculation results at design condition are shown in Figs. 1.5 to 1.7. The open water characteristics with the new wake model calculated by present surface panel method are shown in Fig. 1.8, comparing with the experiment results and a good agreement is obtained.

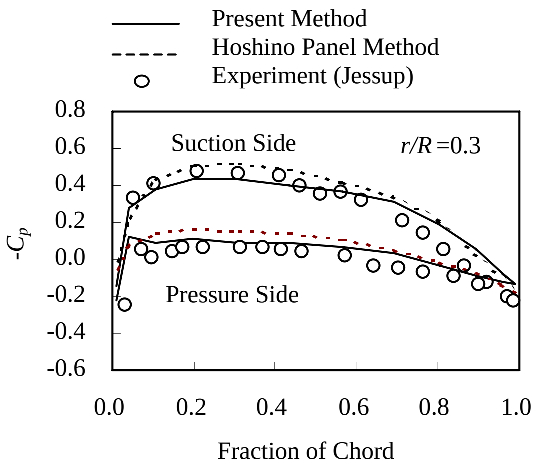

Figure 1.5- Comparisons of pressure distribution at 0.3R.

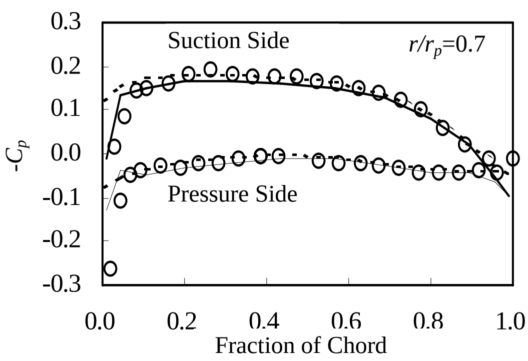

Figure 1.6- Comparisons of pressure distribution at 0.7R.

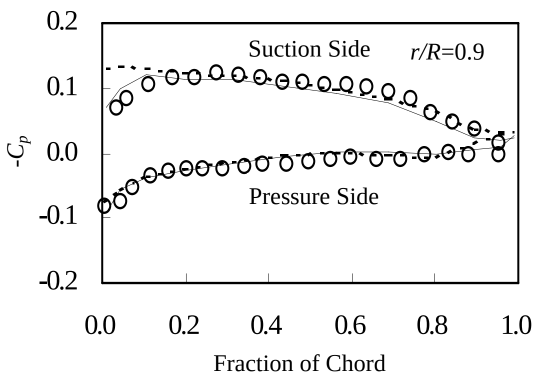

Figure 1.7- Comparisons of pressure distribution at 0.9*R*.

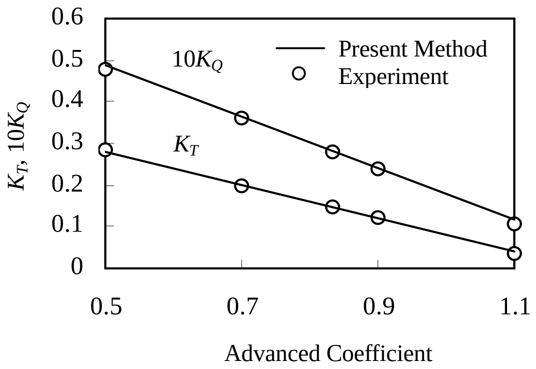

Figure 1.8- Comparison of calculated thrust and torque coefficients with experiment results.

Suggestion. A surface panel method based on perturbation potential method applied to the marine propeller in steady flow has been investigated. Comparisons of the hydrodynamic characteristics on DTRC propeller model calculated by present method with experiment and Hoshino (1989) computation results can lead to the following conclusions:

1. The improvement of iterative Kutta condition, which requires the pressures at the exact location of the trailing edge instead of at the control points on the panels adjacent to the trailing edge, makes the iteration process get convergence faster.
2. The new wake model based on thrust loading coefficient can predict the pressure distribution near the leading edge more accurate compared with Hoshino calculation results.
3. The thrust and torque are in good agreement with the experimental results even for the off-design conditions by introducing viscous effects based on local Reynolds number.

References.

Breslin, J.P. and Andersen, P., 1994, “Hydrodynamics of Ship Propellers”, Cambridge Ocean Technology Series 3.

Ghassemi, H., Ikehata, M. and Yamasaki, H., 1995, “An Investigation of Wake Model and Its Effect on the Hydrodynamic

Performance of Propellers by Using a Surface Panel Method", Journal of the Society of Naval Architects of Japan, 178, 83-91.

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2. COMMITTEE REPLIES

2.1 Reply of the 24th ITTC Propulsion Committee to Mehmet Atlar, Robert Mutton and Martin Downie

We should like to thank Professor Atlar and his colleagues for their very useful contribution on the effect of coating on propeller performance, which was not included in our Report.

As oil prices continue to increase, fuel economy is becoming extremely important in the marine industry. A propeller coating is important for protection against marine fouling and to improve propeller efficiency over a long service time. Investigations into the influence of the propeller coating on the open water characteristics and the cavitation behaviour of model propellers can be difficult. The thickness of the silicone based coating is typically about 0.025mm and the surface should be very smooth at the leading edge.

The activities in propeller coatings should be continued. This includes especially full-scale measurements and observations regarding the propeller fouling, and monitoring the propeller performance and the resistance against cavitation (damage of the coating). We should like to recommend that the next Propulsion Committee review developments in this area.

2.2 Reply from the 24th ITTC Propulsion Committee to Stuart Jessup

A tolerance of ±0.05mm is specified for the edge sectional shape (leading, trailing and tip edge geometry). In general, an anti-singing edge, if specified in the propeller data, is added after a propeller has been designed without considering the anti-singing edge during the design process. Therefore, for model propellers with a large trailing edge thickness or with a large diameter, the addition of an anti-singing edge at the trailing edge could change the thrust because it effectively changes the camber. For small model propellers, say with diameter smaller than 250mm, the addition of anti-singing trailing edge may not affect the thrust because the thickness at the trailing edge is small anyway.

2.3 Reply from the 24th ITTC Propulsion Committee to Tao Jiang

The Propulsion Committee would like to thank Dr. Jiang for his contribution and for clarifying his proposed method for obtaining resistance and power data in shallow water.

2.4 Reply from the 24th ITTC Propulsion Committee to Do Ligtelijn

The Propulsion Committee appreciates Ir. Ligtelijn's information that appears to be very valuable to the ITTC community. We certainly would like to recommend that the next Propulsion Committee look into the data and make use of the data to enhance the predictive capabilities for cavitation and unsteady hull pressure fluctuations.

2.5 Reply from the 24th ITTC Propulsion Committee to Tom van Terwisga

The Sasajima-Tanaka method (Sasajima et al., 1966) can be used to estimate a full-scale wake based on model wake. Although this method has not been fully validated by velocity measurements at full-scale, it is indirectly verified by good agreement between measured blade pressures at full-scale and computations, such that the method offers a reasonable estimation of a full-scale wake (Ukon and Yuasa, 1992). Advanced CFD codes can be used to estimate full-scale wakes. Reliable validation data on the full-scale wake distribution and further development of CFD codes are strongly recommended.

As to the full-scale wake simulation methods, a wire mesh screen and/or dummy model are widely used in small and medium size cavitation tunnels. In large cavitation tunnels, a complete ship model is used with a proper correction for blockage effects. Flow liners are widely used to account for the blockage effect, (ITTC 1990 and 1993). In very large cavitation tunnels, the flow liner method is not economical because of its size. A shortened ship model can also be used instead of liners. Boundary layer control by suction or injection around the ship model hull can also be used. The latter two methods are more costly than the flow liner method.

Development of CFD codes is inevitable to obtain reliable wake distributions and to establish the full-scale wake simulation for the cavitation tests. On the other hand, the development of simple but effective experimental techniques is one of the most important future tasks for the ITTC community in order to simulate high Reynolds number flow effects at model scale, including full-scale wake, tip vortex, rudder surface flow and so on.

Regarding the question on efficiency improvement, it is difficult to prioritise the various methods. Coatings certainly appear to be an attractive method of improving efficiency. We agree with the discusser that it is timely to explore various propulsor concepts using advanced CFD methods to improve efficiency.

References.

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Sasajima, H., Tanaka, I. and Suzuki, T., 1966, "Wake Distribution of Full Ships", J. of the Society of Naval Architects of Japan, Vol. 120.

Ukon, Y. and Yuasa, H., 1992, "Pressure Distribution and Blade Stress on a Highly Skewed Propeller", Proc. of 19th Symp. on Naval Hydrodynamic, Seoul.

2.6 Reply from the 24th ITTC Propulsion Committee to Yanying Wang and Lijun Zhang

The discussers addressed a propeller performance prediction methodology based on a potential flow formulation and numerical solution by a Boundary Element Method (BEM). In particular, the importance of features such as trailing wake modelling, pressure-based Kutta condition and viscous-flow correction for hydrodynamic loads is highlighted. The Committee agrees with the discussers that these features are fundamental to achieve accurate propeller performance predictions by BEM, as clearly reviewed by previous ITTC Propulsion Committee Reports and many researchers in this topic.

Regarding the wake alignment, the 24th ITTC Propulsion Committee presented some recent developments that offer further enhancements of standard BEM. They include trailing wake alignment techniques to describe the slipstream flow and to predict wake pitch and contraction under more general flow conditions than wake models based on momentum theory and semi-empirical approaches. Wake alignment is beneficial to predict blade loads at off-design conditions, although it should have a limited rôle on pressure distribution in the leading edge region, which is more influenced by other factors such as surface discretization and numerical evaluation of velocity as the gradient of the potential.

Similarly, pressure-based Kutta conditions are helpful to describe pressure distribution in the trailing edge region in the case where three-dimensional and unsteady flow effects are dominant. Unfortunately, a rigorous derivation of a zero pressure jump condition for the velocity potential at the trailing edge is beyond the limits of low-order panel methods, and some attempts to study propeller flow using higher-order formulations have been presented.

In relation to viscous-flow corrections, coupled potential-flow and boundary-layer solvers have been proposed to determine the friction coefficient as a function of the actual flow on the propeller surface. Because of the possible need to distinguish between laminar and turbulent flow regions and to detect flow separation regions, these methods should be preferred to those based on simple expressions relating friction with the local Reynolds number.

The Committee wishes to thank the discussers for their useful contribution.